
RESEARCH ARTICLE

Distribution and abundance of aquatic macrophytes in a forested stream: Case study in Kottawa Forest Reserve

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Abstract Forest ecosystems have been studied for terrestrial components and other faunal assemblages while information on aquatic plants on this regard is scarce. Thus, present preliminary study was designed to study the abundance, distribution and factors influencing on aquatic plant distribution in forested stream selecting “Gong Gawwa Ela” locate in the Kottawa forest reserve. Six sites were selected along a stretch of the stream (~1 km). Those sites were visited once in every month for a period of three months. For each site, plant distribution was observed in a transect across the stream perpendicular to the river bank. Water quality, water flow velocity and sediment composition at each site were also monitored. Eleven aquatic plant species were found along the stream while the most common species were *Lagenandra thwaitesii*, *Aponogeton rigidifolius* and *Adiantum* sp. A significant difference in plant diversity among study sites was noticed where the highest plant diversity was found in the most downstream site. Irrespective to the species; distribution of above three species exhibited a significant positive correlation to the sediment composition. Further, diversity of aquatic plant was significantly correlated to the abundance of *L. thwaitesii*. There was no significant difference in dissolved oxygen, pH, temperature and biological oxygen demand among study sites. Present study revealed that sediment composition and the abundance of *L. thwaitesii* are two factors that decide the architecture of the aquatic plant communities along this stream.

Keywords: *Forested stream, Sediment, Water flow, Aponogeton, macrophytes*

Introduction

Forested streams are critical elements of forest ecosystems as these aquatic habitats are rich in biological diversity. Beside to biodiversity, streams provide opportunities to transfer energy and material from upstream to downstream and vice versa. Further, streams laterally connect to the terrestrial ecosystem via the riparian zone while vertically connect to the atmosphere at the air water interface and link underline sediments at the bottom. Thus, streams connect with different microhabitats in ecosystems and involve in an array of ecosystem functions essential to maintain integrity of the forest ecosystems. Therefore, biotic elements including aquatic plants and other organism are particularly important to maintain ecosystem functioning in these ecosystems.

Macrophytes are photosynthetic aquatic plant, easily identify through naked eye. These plants grow permanently or periodically submerged, floating, or growing up through the water column and provide an array of ecological functions. Those functions include provisioning of habitats, refuge and food for fish and invertebrates, primary production and the regulation of sediment transportation and contribution to the biogeochemical cycles etc.(Bornette and Puijalon, 2011, Folkard, 2011, Nepf, 2012). Further, aquatic vegetation influences to the architecture of aquatic ecosystems while simultaneously plant communities are impacted by the dynamic nature of the aquatic systems.

Even though studies on forest ecosystems, (Gunatilleke *et al.*, 2006, Gunatilleke and Gunatilleke, 1985, Pemadasa and Gunatilleke, 1981), fish and other faunal assemblages in the forested

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streams (Pethiyagoda, 1994, Wikramanayake, 1990, Wijesinghe and de L. Brooke, 2005, Wikramanayake and Moyle, 1989) have been reported in the literature, information on aquatic plants in the forested streams is scarce to our knowledge. Further, factors behind the distribution and abundance of macrophytes in the forested streams are not well documented. This information is useful in forest ecosystem management and conservation. Thus, to fill this information gap, the present study was designed to study the distribution of aquatic plants and factors behind their distribution along the forested stream (*Gong Gawwa Ela*) locate in the Kottawa rain in Yakkalamulla, Sri Lanka.

Material and Method

Description for the study site

The studied steam (*Gong Gawwa Ela*) start in the Kottawa rain forest ($6^{\circ} 5'40.54''N$ and $80^{\circ}19'26.75''E$) which locate in the Yakkalamulla Grama Niladhari Division that belong to the Yakkalamulla Divisional secretary's Division of the Southern province of Sri Lanka (Fig. 1). The forest complex situated on a flat terrain located approximately 50-200 m above the sea level.

Six study sites were selected in a strip (~1 km) along the stream (Fig. 1). Three sites (S1, S2 & S3) located in the upstream while other three (S4, S5 & S6) were in the downstream. Site one was selected as for the reference site. This site (S1) was totally free of anthropogenic influences as it locates inside the forest reserve (Fig. 1). Other sites were selected along the stream, by considering following three factors; (i) presence of the aquatic macrophytes, (ii) surrounding land use, and, (iii) accessibility. Each site was visited once in every month from September to November in 2016.

Aquatic plant abundance was very less along this stream. Therefore, a transect perpendicular to the river bank was demarcated across the stream and all plants found along the transect were surveyed. Number of individuals per each species was counted and the plant species were identified using identification manuals. After being identified, Shannon-Wiener index and the species richness were calculated to compare the plant diversity among study sites.

Water quality parameters including dissolved oxygen content, temperature, pH and conductivity were recorded at the field using a water quality meter (YSI85, USA). Water flow velocity was recorded using a velocity meter (KENEK VP 1000). Nitrate and orthophosphate concentrations were measured

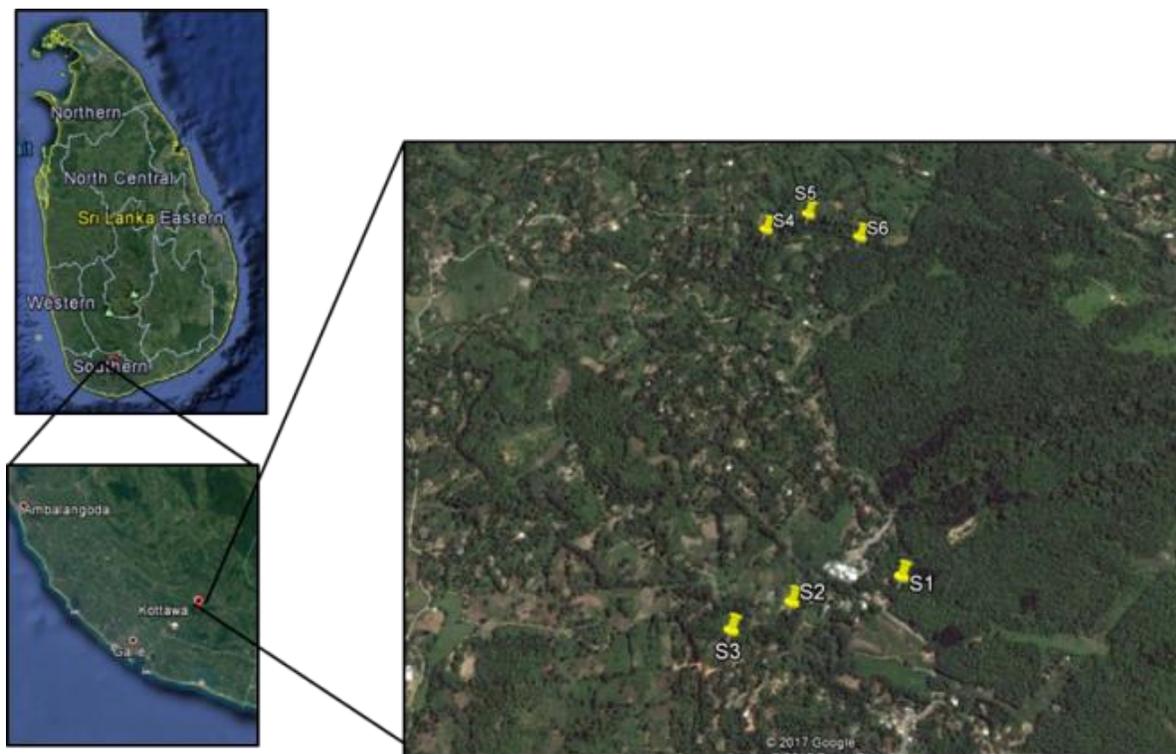


Figure 1: Location of the study sites (S1 the most upstream site, S6 the most downstream site)

according to sodium salicylate method and ammonium molybdate methods respectively following APHA (1999).

At the same sites, sediment samples were collected and those samples were analyzed after being transported to the laboratory for particle size distribution.

Statistical Analysis

Data presented as either range (Min-Max) or mean ± standard deviation (SD). Study sites were statistically compared using one-way analysis of variance (ANOVA). Pearson correlation was applied to determine the relationship between plant distribution and other factors. Graphics were made by using Microsoft Excel and the statistical analysis was performed using SPSS 16.

Results and Discussion

Eleven aquatic plant species were identified in six study sites (Fig. 2). Among those species, the most commonly found species were *Lagenandra thwaitesii*, *Adiantum* sp and *Aponogeton rigidifolius*. Although *Adiantum* sp was found in all study sites, *Lagenandra thwaitesii* was absent in the S1. These two species found along the outer margin of the stream, where the water level was either zero or very low. *Aponogeton rigidifolius*, the third most common species was found only inside of the stream of S1, S2, S3 and S4

sites(Fig. 2).

There were significant differences in percentage cover of the *Lagenandra thwaitesii* ($F = 46.4, p < 0.05$) and *Aponogeton rigidifolius* ($F= 25.6, p < 0.05$) among study sites. The abundance and percentage cover of *Adiantum* sp were independent form the location ($F = 0.360, p < 0.05$). As *Lagenandra thwaitesii* found at the outer margin of the stream close to the river bank, those plants act as a barrier against the river bank erosion. Site one supports for growing plants naturally compared to other sites as this site locate inside the Kottawa forest reserve. Thus, site one is free of anthropogenic influences due strict regulations enforced by the Department of Forest Conservation, Sri Lanka. However, site one received less sunlight compared to other locations because of the shading effect of the forest. According to the field observation, surrounding lands of the other study sites (except site 1) were used for tea plantations where the surface runoff of those lands directly add to the stream. In particular, S3 was very close to a land belong to a tea plantation. The highest number of plant species was found in the most downstream site of S6 (Fig.2).

Occurrence of aquatic macrophytes in an aquatic system depends upon a combination of factors including sediment characteristics, nutrient quality of water and sediments and other physicochemical parameters of the environment (Bornette and Puijalon, 2011, Atapaththu and Asaeda, 2015). Comparatively higher contents of nitrate and phosphate were detected in sediments collected at the S6 (Fig 3). The same site consists of the highest

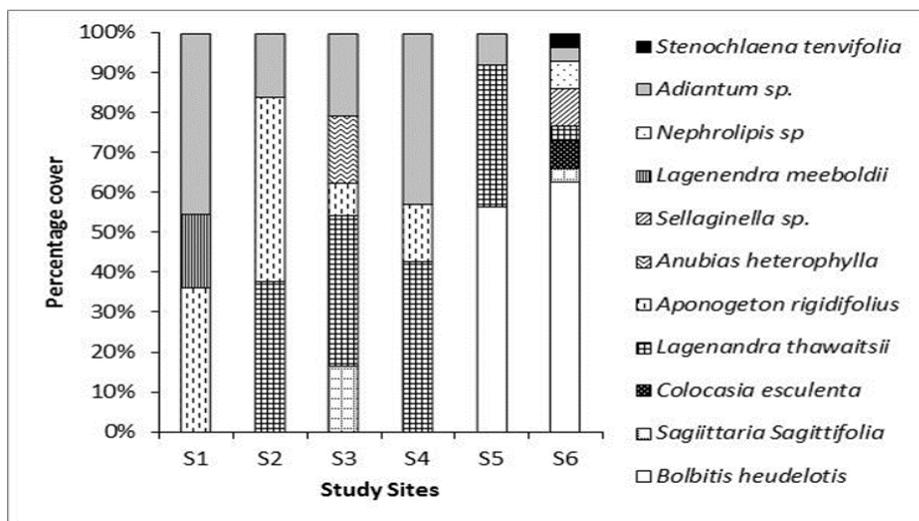


Figure 2: Distribution of different plants species in study sites

number of plant species (Fig 2).

Water quality among study sites was not statistically different, and comparably a similar condition was observed along the stream (Table 1). Nitrate and phosphate concentrations detected in this study were comparatively similar with the values recorded by Madushanka *et al.* (2014) for Dedyagala stream, in Southern Sri Lanka. Water quality analysis indicated good quality of water in terms of aquatic pollution.

Abundance and distribution of aquatic plants are controlled by several abiotic factors (Madsen *et al.*, 2001, Bornette and Puijalon, 2011, Bornette and Puijalon, 2001, Wijewardene *et al.*, 2014). Irrespective to the species, the most common three plants (*Lagenandra thwaitesii*, *Aponogeton rigidifolius* and *Adiantum* sp) prefer to grow in sediments that consist of a larger fraction of fine sediments (Fig. 4), and there was a significant positive correlation between percentage cover of

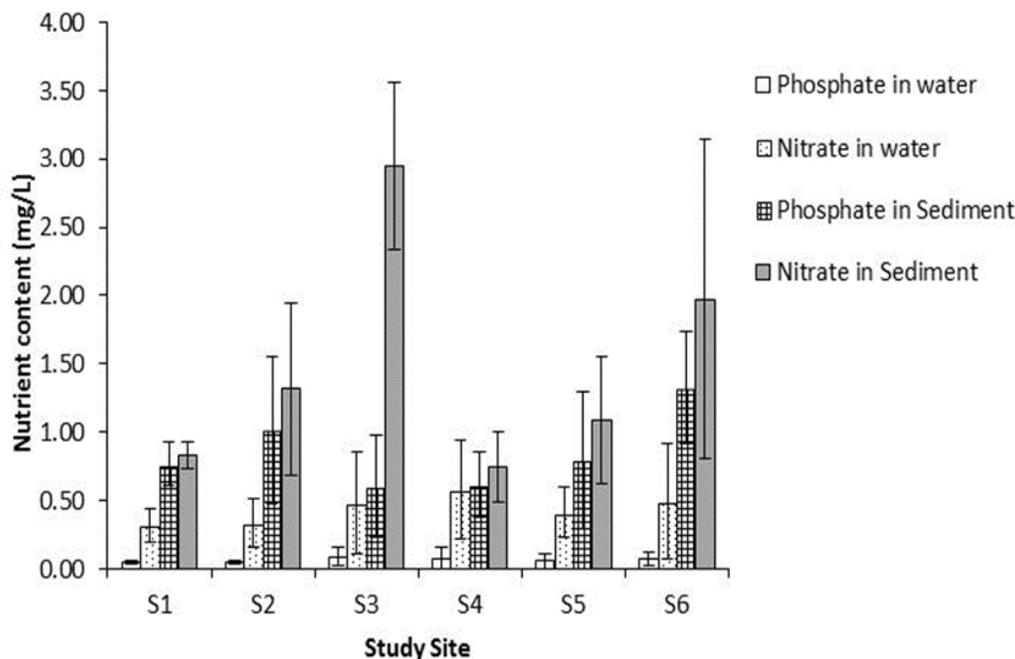


Figure 3: Nitrate and phosphate concentrations of sediments and water

Table 1. Water quality parameters of the study sites

Parameter	Study Site					
	S1	S2	S3	S4	S5	S6
pH	7.07 ± 0.54	6.95 ± 0.65	6.96 ± 0.54	7.04 ± 0.57	7.40 ± 0.50	7.10 ± 0.48
Temperature (°C)	27.5 ± 1.2	27.6 ± 1.1	27.6 ± 1.3	27.7 ± 0.7	27.3 ± 0.5	27.1 ± 0.9
Conductivity (µS)	162.1 ± 82.5	166.1 ± 91.6	170.6 ± 92.4	159.9 ± 94.1	153.3 ± 79.1	258.2 ± 179.3
DO (mgL ⁻¹)	8.06 ± 0.10	6.28 ± 2.86	6.75 ± 2.05	8.80 ± 0.45	9.64 ± 0.73	8.90 ± 0.31
BOD (mgL ⁻¹)	0.97 ± 0.91	1.38 ± 0.72	0.60 ± 0.20	0.60 ± 0.20	1.48 ± 0.91	1.01 ± 0.44
Flow velocity (ms ⁻¹)	0.02 - 0.13	0.04 - 0.14	0.04 - 0.19	0.11 - 0.28	0.15 - 0.41	0.05 - 0.33

(Note Flow velocity in Min-Max range)

aquatic macrophytes and coarse sediment content to fine sediment content ratio ($r^2 = 0.537, p < 0.05$).

Further, the observed trend for the occurrence of different plant species along the stream (Fig. 2) agree with the trend observed for the plant diversity (Fig. 5). The highest diversity was found in the most

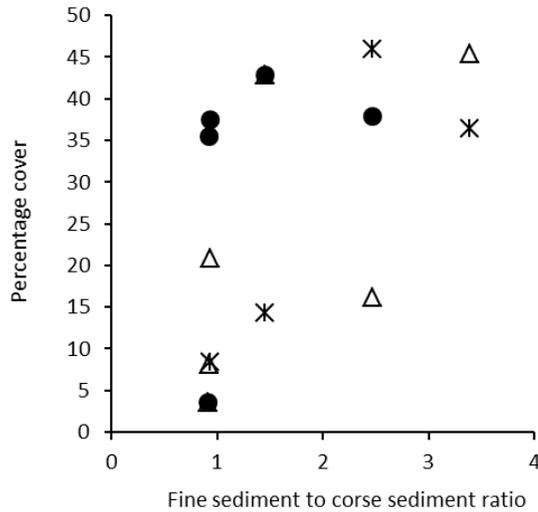


Figure 4: Relationship between percentage cover of aquatic plants and the fine sediment to coarse sediment ratio (Size of the fine sediments are less than 500 μ while particles bigger than 500 μ are coarse sediments). ●: *Lagenandra thwaitesii*, *: *Aponogeton rigidifolius* and Δ: *Adiantum sp*

There was a significant difference in plant diversity and it was clearly detected (Fig. 5) using Shannon-Weiner diversity index ($F=20.8, p < 0.05$) and species richness ($F=29.2, p < 0.05$).

downstream site of S6. Aquatic plant diversity along the stream is a function of *Lagenandra thwaitesii* abundance (Fig. 6). Former trend was explained by the significant negative correlation ($r^2 = -0.971, p < 0.05$) between species richness and the percentage cover of *Lagenandra thwaitesii* (Fig. 6). Further, Shannon-Wiener diversity index negatively

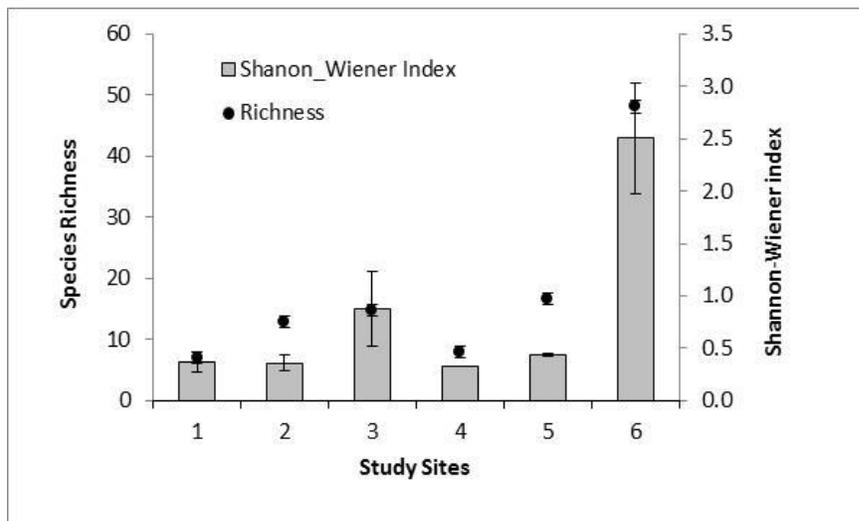


Figure 5: Aquatic plant diversity among study sites

correlated to the abundance of the same species.

Lagenandra are exclusively found in river biotopes (Graaf and Arends, 1986) and this species is an important aquatic plant for river ecosystem as it

regard is yet to be addressed, thus, further studies are recommended.

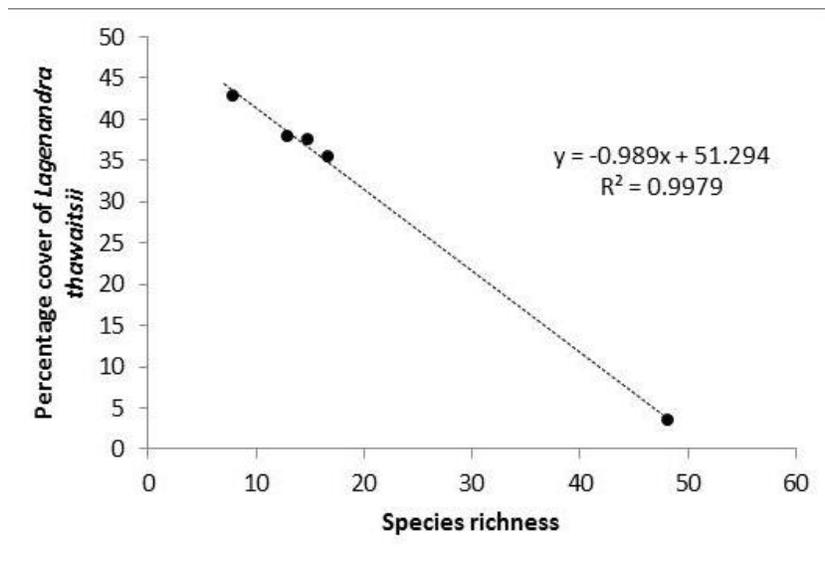


Figure 6: Relationship between Species richness and the percentage cover of *Lagenandra thawaitsii*

involve in numerous ecosystem services. For instance, root system of this plant has an ability to stabilize the riverbank through their specific root architecture (De Silva et al., 2012). Further, well developed root system accumulates sediments inside plant canopies.

A. rigidifolius was only found in three locations (S1, S2 and S3) and this plant exclusively found inside the stream where water flow is available. As *A. rigidifolius* grow inside the stream, it provides shelter and refuge for fish as well as for other invertebrates. Further, ribbon like leaves of *A. rigidifolius* act as a substrate for attached algae. Therefore, patches of *A. rigidifolius* are microhabitats which facilitate an array of ecological roles to keep the integrity of the river ecosystem.

Conclusion

Present study revealed that sediment composition, water flow velocity and the abundance of *Lagenandra* sp are the important factors that influence to the architecture of the aquatic plant communities along this stream. This basic information will helpful to understand the interactions of aquatic macrophytes in forested streams and probably benefit in forest ecosystem management. As present study mealy focused on the spatial variations in macrophyte distribution, information on temporal scale in this

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